IS ACTIVE LEARNING POSSIBLE OUTSIDE THE CLASSROOM?

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Peer instruction is an active-learning method developed by physicist Eric Mazur at Harvard University in the early 1990s. It has enjoyed considerable success among science instructors, and has been adopted at an incredible rate throughout the world (Mazur 1997; Crouch and Mazur 2001; Lasry, Mazur, and Watkins 2008; Lasry 2008; Meltzer and Thornton 2012; Henderson 2008). The typical Peer Instruction (PI) script begins with the instructor giving a brief presentation (5-7 minutes) followed by a conceptual multiple-choice question. Students are then asked to select an answer (often with a wireless handheld clicker, but equally effective with flashcards or raised hands). They are then asked to convince a neighbour who has a different answer. Students engage in a process that forces them to verbalize their thinking, listen actively to their peers, and reflect critically on the subject matter. After this brief discussion, students resubmit an answer to the teacher, who can then use this feedback in real-time to tailor the instruction to the conceptual state of the class.

Although the efficacy of peer instruction has been systematically documented (Mazur 1997; Crouch and Mazur 2001) in different academic contexts (Lasry, Mazur, and Watkins 2008; Smith et al. 2009), to date, this learner-centred approach has been confined to brick-and-mortar classrooms. Could students take advantage of this instructional strategy outside of class? Could Peer Instruction be used in flipped classrooms or distance education for instance? More generally, could peer instruction be used asynchronously?

We set out to develop an asynchronous peer-instruction platform called DALITE (for "Distributed Active Learning Interactive Technology Environment"), which we then evaluated as part of a study.[1] This article describes how the DALITE works, whether it promotes conceptual learning more than traditional lecture-based teaching, and if learning gains differ when compared with face-to-face peer instruction. We also document the socio-cognitive and affective implications of using DALITE for students, as well as the tool's educational implications for teachers.

THE PROBLEM: CONCEPTUAL CHANGE

In science, several basic concepts are counter-intuitive. Therefore, a number of students experience difficulty acquiring a firm understanding of fundamental concepts, concepts as simple as acceleration. For instance, take a projectile launched vertically. At the top of its trajectory, the object is temporarily stopped. Is it subject to an acceleration? Before giving the answer, let us reiterate that this question is either not straightforward or counter-intuitive to many students. Many students will state that the object is not moving. Hence, it should not have an acceleration. Yet, that is false. Acceleration is not related to velocity but to the *change* of velocity. The object is always changing velocities, hence it is always accelerating. Viewed differently, the projectile is subject to gravity at all times, and consequently is always experiencing an acceleration. It slows down while rising and speeds up while falling. It accelerates at every point of its trajectory, including at its highest point, where velocity is zero.

Given that students come to class with an elaborate but often incomplete or erroneous comprehension of the basics—such as acceleration—it is not enough to explain these core concepts to make them immediately understandable. Instructors must first explore their students' preconceptions in order to ensure learning via *conceptual change* (Chi, Slotta, and De Leeuw 1994).

Inspired by constructivist and socio-constructivist theories, and their learning models, instructional methods collectively known as *active learning* have emerged from innovative educational practices. A body of research shows clear improvements in conceptual learning among students in an active-learning context (Meltzer and Thornton 2012; Freeman et al. 2014). Several studies on conceptual change indicate, *inter alia*, that learning is enhanced when instruction includes student-centred learning activities (Sinatra and Pintrich 2003; Chi et al. 1994; Palincsar and Brown 1984) and employs collaborative practices (Stahl 2006; Charles and Lasry 2010; Charles, Lasry, and Whittaker 2013). Accordingly, we geared the development

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of our innovation (which is aimed at conceptual change) toward an active-learning context—more specifically, one of peer instruction like Mazur's. Peer instruction however, typically addresses the conceptual change problem within brick and mortar classrooms. We set out to investigate whether providing students with an asynchronous peer instruction platform could extend the peer instruction process outside of classrooms.

THE DALITE PLATFORM

In its simplest version, DALITE enables students to use peer instruction online asynchronously. Each student accesses the system on the Web, from either a computer or a mobile device. Like classroom peer instruction, the platform features multiple-choice questions students must answer; they are then asked to explain that answer in writing. This step differs from conventional peer instruction, as explanations must be in written form, and students must all provide a rationale for each response selected.

Each written rationale is then stored in a database (repository) that houses all explanations generated by students. Having submitted their choices and explanations, students get to the next screen and receive three or four explanations written by peers for the same choice as the one they selected as well as three or four explanations for a different choice. One of these two sets of explanations always corresponds to the correct answer, but students do not know which it is. The process engages them in an asynchronous dialogue with their peers: they must evaluate the many rationales concerned, and then select the most convincing response. This forces them to continually reflect critically on their own ideas and those of their peers. The last step consists in displaying students' first and second selections, and giving them an "expert" rationale drafted by the instructor (without explicitly stating "the" answer).

There are a few major differences between asynchronous and classroom peer instruction. Foremost, in DALITE, students must express their ideas in written form whenever they answer a question. All student-generated responses are used to construct a repository that constitutes the platform's "backbone". Another difference is that the system always gives student an opportunity to consider another viewpoint; students are always given explanations for the correct answer and if they began with the correct answer they are always given a strong distractor to evaluate as well. In classroom peer instruction, if neighbors have the same answer, little discussion can take place. Furthermore, the effectiveness of student-generated explanations increases with usage because students evaluate answers and provide the system information to automatically select explanations that students perceive as the best.

The DALITE platform was designed to give students access to peer instruction outside of class, and has become an ideal tool for physics instructors who want to "flip" their classrooms. With a computer or mobile device, students can log onto the system, explore the concepts covered in the course, and interact with their peers, thanks to a repository of rationales furnished entirely by students. (The "expert" answers come from a different database.)

On the instructor side, DALITE also displays results such as students' first and second choices of response for each question. At the same time, a special function allows them to see students' rationales for a given question, meaning they can determine to what extent their students understand key concepts (whether to prepare for their classes or to assess comprehension after each class and make the necessary adjustments to course content and instructional activities).

RESEARCH QUESTIONS

As part of the study, we wanted to ascertain whether using DALITE would result in more in-depth conceptual understanding than that produced by the traditional classroom method of peer instruction. We also evaluated the conditions that facilitated or constrained use of the tool by students and teachers. Our four main research questions were as follows:

- Does an asynchronous online peer-instruction system such as DALITE promote more conceptual learning (conceptual gains) than traditional instruction?
- How do learning outcomes obtained with DALITE compare with those of face-to-face peer instruction?
- What are the socio-cognitive and affective implications of DALITE use for students?
- What are the educational implications of DALITE use for educators?

These questions required the use of various research methods, accompanied by the collection of quantitative and qualitative data as described below.

PART 1: QUANTITATIVE DATA

We compared the conceptual gains made with synchronous and asynchronous peer instruction. We used a quasi-experimental design that included five sections of an introductory physics course, given by four teachers at three different English-language colleges.

> *Several studies on conceptual change indicate,* inter alia, *that learning is enhanced when instruction includes student-centred learning activities.*

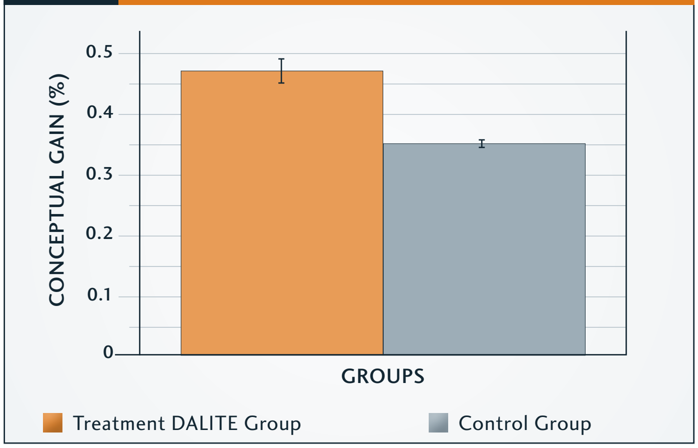
In all, 137 students aged 17 to 19 enrolled in the first year of the Science praogram took part in the study, and formed the treatment (DALITE) group. The control group was composed of two cohorts. The first was draw from a large database of Force Concept Inventory (FCI)[2] outcomes from North American institutions, from which we extracted a subset of students with the same level of incoming proficiency (N = 2912) as that of our treatment-group participants. This cohort was composed of students who had mostly been taught via the traditional lecture approach. The second was comprised of college and university physics students in a classroom peer-instruction context who *did not have* access to DALITE (N = 188). Both instructors had been using active-learning methods for a number of years. Comparison with such a sample seemed essential if we were to ensure that our results were authentic and significant.

In the treatment sections, students were given online DALITE assignments every week, with instructors commenting on this homework in class. The same questions were posted on the platform by each instructor, but at different times during the course. We compared the conceptual gains[3] of students who had used DALITE to those of students who had been taught using the traditional lecture method (with neither peer instruction nor DALITE) in the large comparison cohort (N = 2912). Our results show that students using DALITE had statistically significantly greater conceptual gains than those of the control group (see Figure 1).

We then compared the results of students who had used DALITE to those of students who had experienced synchronous classroom peer instruction. We found no statistically significant difference in conceptual gains between the synchronous and asynchronous groups. This suggests that our online platform promotes conceptual gains as much as the traditional peer-instruction method.

Although the four instructors concerned used DALITE in their courses, no statistically significant difference was found to exist between the conceptual changes experienced by students in these different sections.

FIGURE 1 CONCEPTUAL GAINS AT END OF SEMESTER



PART 2: QUALITATIVE DATA

We opted for a case-study design involving conditions that promoted DALITE use by students and faculty. Five aspects were evaluated.

1 How does DALITE promote conceptual gains?

Our data suggest that the conditions and context for the tool's success depend on combining it with an active-learning approach. To determine whether DALITE makes students reflect in greater depth, we interviewed 23 of them individually. Of those interviewed, 70% mentioned that using DALITE had helped them think more seriously about the concepts to be assimilated. Next is an example of this type of comment.

[2] The FCI is a diagnostic test for postsecondary introductory-physics courses. It consists of 30 plain-language multiple-choice questions for which students do not have to perform any calculations. All incorrect answers contained in the test are taken from a database of erroneous responses that have frequently been given by students in interviews. This test is often given at the beginning and end of the course (Pre-Post testing) to assess what students have learned and measure their conceptual gains.

[3] Conceptual gains correspond to the Post-Pre difference on the FCI divided by the maximum possible increase in score (i.e., by the number of incorrect answers given on the Pre-test). This formula is often called the Hake-gain.



I want to know which one makes more sense… there is one side [that] convinces you so much, and you like, OK, it must be that [answer]. But then in the back of your head, you know these other people make a good point. So then you get conflicted.

In short, DALITE seems to help students appreciate the value of coming up with their own explanations—especially the value of their written rationales. The attendant conditions and context seem related to the time at which students realize their effects on their peers.

2 Can using DALITE help students generate self-explanations? If so, what role do written rationales play in the process?

The DALITE repository, which allowed us to collect more than 7,000 written rationales from students, showed that the tool can be used to facilitate the generation of self-explanations. The data also suggest that, by and large, students took matters seriously: upwards of 75% completed all tasks assigned. While they could "get by" with short rationales, about half of them provided very detailed explanations (according to the average number of words used). This observation is interesting, as there is a modest social component to DALITE rationales. As previously mentioned, the rationales generated by students form part of the tool's database, and can therefore be selected at random and shown to future students. This might explain why some students, knowing that their explanations might be shown to their peers, opted to draft in-depth explanations for most of their answers. Was this their way of contributing to the study, or merely of putting their ideas into concrete form? If we are to believe their own accounts, the second hypothesis is plausible:

I find that it helps you out to write it down, because it's much easier to say "oh yeah I understand that" but then to try and explain it in words, to be concise, it really shows you understand the matter. It helps out a lot.

This may also be due to the combined effect of social and cognitive factors. The comment below is particularly noteworthy, as the student in question admits having found the rationales of others disjointed and hard to read. This seems to have made her take more care in drafting her own rationales; she realized that others would be trying to understand her reasoning. This is what she had to say:

I used to write short rationales just thinking why I thought this was the answer, but now I explain the concept behind it and everything, so I give more detailed rationales…at first I found it like all over the place and choppy, but then I got used to it like being somebody's thinking, so it's easier to read now…. Since you have to present it, you have to say "OK this is what we think and why." It organizes your thoughts.

3 Can using DALITE promote the cognitive processes of comparison and contrast?[4]

Engaging the cognitive processes of comparison and contrast is a major feature of the platform. The 23 students interviewed show they recognized that fact, and were aware of the learning support it represented. Below comments illustrate this point:

Yeah... when you try to explain [to] yourself and you're still not sure, and then you give your answer and you can read through everybody's rationales, you're able to make sense of what you're saying, and see where your thought process might have been wrong or what the other people's thought process is. And, you can look at what answers actually make more sense to you. So I guess it helps because you're seeing other people's point of view and sometimes you like theirs better.

4 Did students develop enough expertise to identify deep (rather than surface) conceptual similarities? Can using DALITE promote the transfer of learning to other contexts? Can students recognize that two different situations have similar contexts, and continue to learn in this manner?

Our data suggest that students are able identify deep structural similarities when surface characteristics differ. These findings indicate, however, that this ability is linked to three factors.

First, the type of question is important. In certain cases, recognizing a context similar to two different situations was easy; in other cases, it was more complex. This would seem to indicate that, in the future, we will have to examine more closely the way questions are worded, so as to establish characteristics that help students identify deep conceptual similarities.

Second, group discussions, even when asynchronous, seem to play a key role in the success of learning transfer. In most cases, asynchronous discussions steered a good number of students toward the right answers.

[4] Comparison and contrast constitute higher cognitive processes as exemplified by Bloom's Taxonomy (Level 4: Analyzing).

Third (and most important), we must understand the similarity between a context of classroom learning and one of learning via online assignments. Courses must be planned so students grasp this connection, which in turn promotes enhanced participation in classroom activities and online assignments. Some of our highest rates of student engagement were obtained in classes where the teacher considered assignments completed via DALITE as a normal part of the course, continuously related DALITE to the course in class time, and used the platform to prepare and consolidate concepts.

5 Can using DALITE promote thought processes that help students learn?

We must develop students' awareness that learning requires action that leads to knowledge acquisition. Our tool showed it was capable of promoting such thought processes. Some students mentioned that doing their assignments via DALITE "taught them how to learn"—as illustrated by the following comments:

> *Usually I look through my book to look at the theory to see this is right … You have to look to your notes to try to get more understanding… at the same time, it forces me to read, not just look at the rationales and then think to myself, yeah I know why [that's the answer]. And makes me like, it forces me to read the rationale and try to understand why it is that answer.*

Lastly, DALITE also gave students a chance to assume more responsibility for learning. One student explained that the rationales in DALITE had helped her learn the "grammar" of physics:

> *…whenever I have to read an English websites with all the terms, I would not understand it at all. And also just the wording, the way the concepts [are] presented was totally different… with the rationales we had to write, I kind of see the structure that's behind them, so it really helps me to understand better the overall concepts... So I read [physics text] better now. I find I can really now see the information better than just many scientific terms everywhere.*

CONCLUSION

This study examines new avenues for promoting conceptual change. It forced our research team to design a tool for promoting and assessing conceptual learning. Our findings suggest that the DALITE web tool we created to provide students with an asynchronous peer-instruction platform works. Our platform can also assist instructors in their efforts to use active-learning approaches while ensuring that learning takes place both inside and outside the classroom.

Generally speaking, the educators that participated in our study mentioned liking the system, although they also said much remained to be done to enhance ease of use. We are currently working on this aspect, as well as on changing DALITE from an interesting prototype to a stable, user-friendly tool that can be used by people in all disciplines.[5] Moreover, we are trying to make it accessible on other online learning platforms such as Moodle and Open edX.

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[5] For the moment, the DALITE platform is available in English only.

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